BIG CYPRESS NATIONAL PRESERVE

GEOLOGIC RESOURCE MANAGEMENT ISSUES

SCOPING SUMMARY

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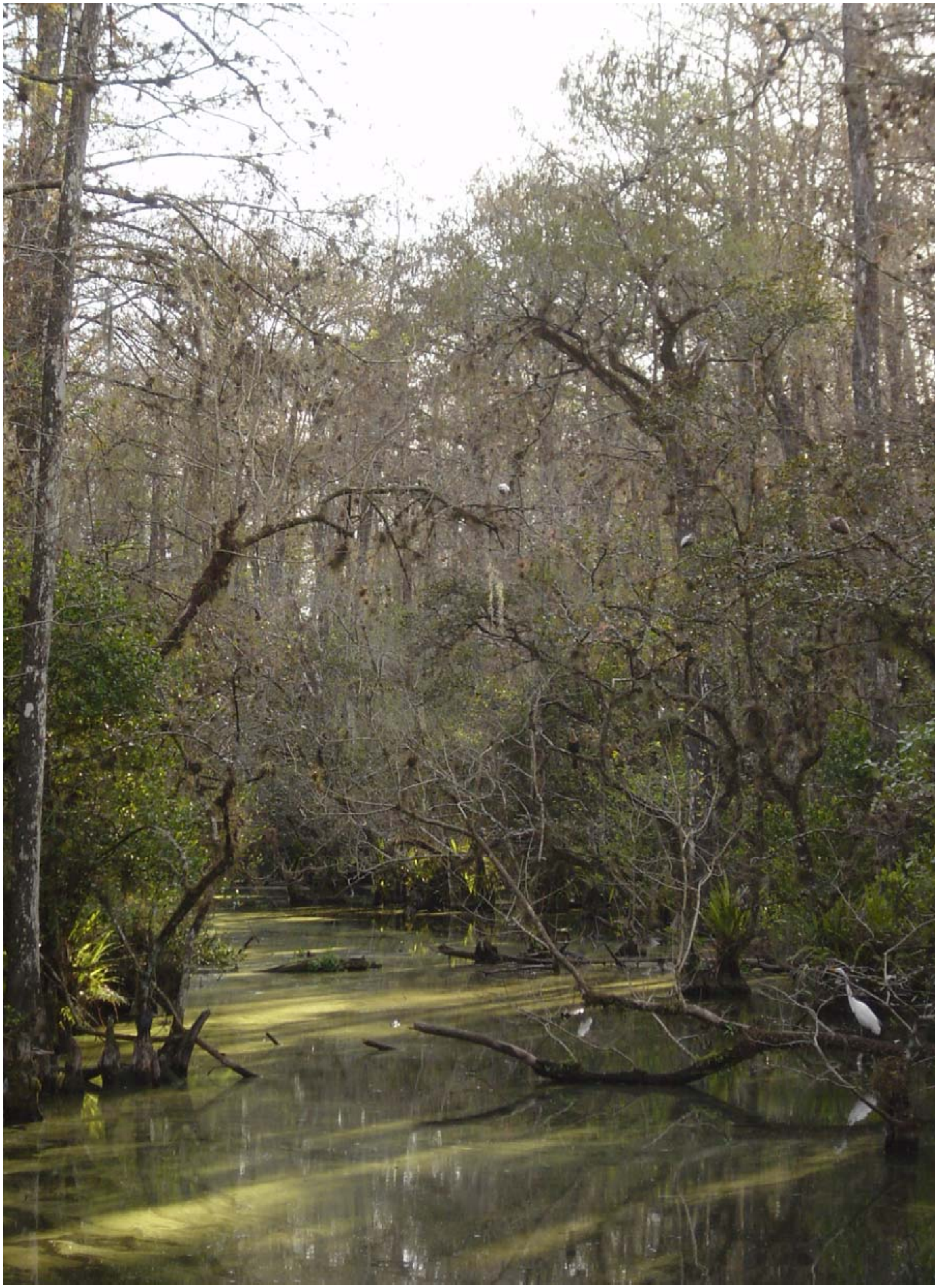

Near Sweetwater Strand in Big Cypress National Preserve. Photograph by Trista L. Thornberry- Ehrlich (Colorado State University).

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Executive Summary

Followed by a field trip on January 28, 2005, a Geologic Resources Evaluation scoping meeting took place at the preserve headquarters on January 27, 2005. The scoping meeting participants identified the following list of geologic resource management issues.

1. The hydrogeologic system at Big Cypress is a western extension of the Everglades. Surface water flows over the low relief landscape through sloughs and marshes. This flow has been altered by roads, canals, and levees at the preserve.

2. Geologic and topographic mapping when combined with flow patterns would help resource management determine which areas to focus on for restoration.

3. Soils and bedrock depth surveys and measurements are needed at the preserve. This in addition to soil recovery research would help resource management deal with ORV damage remediation.

4. Disturbed lands at the preserve include borrow pits and canals dug during the construction of roads and pads for oil and gas drilling. These features disrupt the flow of water and need to be remediated.

5. ORV management is an ongoing process at the park. Implementation of the 2001 ORV Plan is a major management goal. The preserve is trying to designate 644 km (400 miles) of trails to lessen ORV environmental impact.

6. Oil and gas issues include regulating the eight producing wells located within the preserve. Land and mineral ownership rights differ between the surface and subsurface and responsibility for clean- up and remediation is often mislaid.

Introduction

The National Park Service held a Geologic Resource Evaluation scoping meeting for Big Cypress National Preserve at the park headquarters near Everglades City, Florida on Thursday, January 27, 2005. Following this meeting was a field trip on January 28, 2005. The purpose of the meeting was to discuss the status of geologic mapping in the preserve, the associated bibliography, and the geologic issues in the preserve. The products to be derived from the scoping meeting are: (1) Digitized geologic maps covering the preserve; (2) An updated and verified bibliography; (3) Scoping summary (this report); and (4) A Geologic Resource Evaluation Report which brings together all of these products.

Big Cypress National Preserve was established during Gerald Ford's administration on October 11, 1974. Big Cypress covers 720,567 acres of the southwestern corner of Florida. Big Cypress National Preserve was the first national preserve incorporated into the National Park Service. This preserve features incredible biodiversity. The environments protected at the preserve range from sawgrass prairies, mangrove forests, cypress stands and domes, hardwood tree islands, to slow flowing sloughs and marshes. The area covers a large portion of the "western Everglades". The preserve is heavily recreated and contains some of the most productive oil and gas fields in south Florida.

Big Cypress National Preserve identified 37 quadrangles of interest. However, additional coverage of 30 more quadrangles (to the north and west) would add considerably to resource management's understanding of the landscape and watershed at the preserve. The Florida State Geologic Survey (FGS) has digitized a geologic map covering the state from individual county maps at a small scale (~ 1:126,720 or larger). This map only displays 5 separate geologic units (Holocene sediments, Pleistocene - Holocene undifferentiated, Miami Limestone, Shell-bearing sediments, Tamiami Formation) for inside the boundaries of the park.

Other geologic maps covering portions of the quadrangles of interest include the FGS MS6/19, MS 6/20, MS 6/21, MS 6/22, MS 6/24, and MS 6/25 (1:24,000, 2000), Geological Society of America (GSA) Memoir 147 (1:79,000, 1977), the FGS OFMS 67 (1:26,720, Dade County), 66/01 (1:126,720, Monroe County), 62 (1:126,720 , Hendry County), 63 and Series 120 (1:126,720, Collier County), 64 (1:126,720, Broward County), 65 (1:126,720, Palm Beach County), USGS 84- 4068 and 86-4126 (1:134,000 and 1:136,000, 1985 and 1986, respectively). BEM Systems produced a hydrostratigraphy study for Big Cypress National Preserve and a small portion of the Everglades National Park that shows interpolated depth to the tops and bottoms of aquifer and aquitard layers. Additional mapping at a smaller scale will be more helpful for preserve management.

Physiography

South Florida lies within the Atlantic Coastal Plain physiographic province. In the area of Big Cypress National Preserve, it is divided into 5 physiographic subprovinces. The Big Cypress Swamp subprovince defines the western boundary of the Everglades. This area is slightly higher in elevation than the Everglades basin because it is underlain primarily by the coral- rich limestones of the Pliocene Tamiami Formation (3- 4 Ma). This formation is exposed in large areas of Big Cypress. Drainage in the province is primarily to the south and southwest.

The Everglades subprovince forms a south dipping, spoon- shaped low- lying area between the Atlantic Coastal Ridge to the east, the Big Cypress Swamp to the west, and the Sandy Flatlands area to the north. The basin has very low relief. The elevation change is only 3.6 to 4.3 m (12- 14 ft) from the maximum near Lake Okeechobee to sea level. Prior to anthropogenic alteration, this drainage system flowed slowly from north to south.

Bounding the Everglades subprovince on the east is the Atlantic Coastal Ridge. It is comprised of Pleistocene marine limestones covered by thin quartz sand sheets. The subprovince ranges in elevation from 1.5 to 6 m (5 to 20 ft) in the southernmost portions. The width of the ridge ranges from 16 km (10 miles) in southern Miami- Dade County and narrows to 5 to 8 km (3 – 5 miles) further north. Periodically breaching the southern portions of the ridge are sloughs (transverse marshes) oriented perpendicular to the trend of the ridge.

The southern reaches of the Everglades and Big Cypress Swamp subprovinces transition into the Coastal Marshes and Mangrove Swamp physiographic subprovince. The subprovince covers an area from the northeastern part of Florida Bay, around the southern Florida peninsula, and west, into the Gulf of Mexico up to the Ten Thousand Island region never Everglades City. Bands of swamps and brackish marshes sitting just above sea level characterize this subprovince. Freshwater runoff and tidal fluxes cause the salinity to change dramatically. This is why the mangrove, capable of enduring such salinity changes, thrives in this area.

Geologic History of South Florida

Sediment cores indicate that South Florida has been predominantly an area of carbonate accumulation since the Mesozoic.

Late Paleozoic Era – During the Mississippian, the landmass that would underlie the grand carbonate platform of Florida today was not attached to the North American Craton. It is speculated that it was attached to the northwest portion of the African continent (Condie and Sloan, 1998). However, marine carbonates were being deposited over large portions of the area atop a Paleozoic age crystalline basement high, the Peninsular Arch (Pollastro et al., 2000). In the Pennsylvanian, a collision event, known as the Ouachita orogeny sutured the Florida landmass to the continent as Gondwanaland and North America collided eventually forming the supercontinent Pangaea. The land was still submerged and south Florida was located at the junction of the North American, South American, and African plates. Through the Permian, Pangaea remained intact (Condie and Sloan, 1998).

Early Mesozoic Era – At the beginning of the Triassic Period, Pangaea began to break up. During the late Triassic, South and Central America and Africa began to rift away from North America. This established the long- standing passive margin of the eastern seaboard that persists today. The Florida and Cuba blocks detached from northwest Africa and the Gulf of Mexico opened (Condie and Sloan, 1998).

Accompanying the rifting of Pangaea was the widespread extrusion of volcanic rocks consistent with mantle plume upwelling due to crustal tension (Heatherington and Mueller, 1991). This continental rifting also opened the Atlantic Ocean basin.

Middle Mesozoic Era - Underlying the south Florida basin are igneous rhyolitic - basaltic rocks (Thomas et al., 1989). These rocks were subaerially exposed and eroded during the late Triassic to middle Jurassic. This caused the formation of redbeds locally. As the Atlantic Ocean continued to develop, deltaic and shallow marine sediments were deposited in the late Jurassic. Restriction of marine circulation at this time resulted in periodic accumulations of evaporites and marine carbonates (Cunningham, 2005). Deposition of Jurassic and Cretaceous sediments was controlled by the south- southeast plunging axis of the Peninsular Arch. Basal sediments onlap and pinch out against the arch (Pollastro et al., 2000).

Late Mesozoic Era – As marine transgression proceeded during the early Cretaceous, the Florida Platform was the site of more widespread deposition of marine limestones and reefs. Further transgression and global warming during the Late Cretaceous established an open marine accumulation of carbonates over the entire Florida Peninsula.

Cenozoic Era – Cenozoic development of the Florida Platform included additional deposition of marine carbonates and deposition of siliciclastics (grains of silicate minerals such as quartz in lieu of carbonates) from northwestern highlands sources and long shore oceanic currents. Tertiary faulting occurred south of Florida as the Cuban block collided with the Antilles arc and carbonate accumulation continued in Florida (Condie and Sloan, 1998). In southern Florida, the open marine setting continued during the Paleocene as more restricted flow to the north resulted in deposits of mixed carbonates and evaporites. Eocene and Oligocene deposition is marked by shallow water carbonates. Intermittent with this deposition were subaerial exposures associated with local oceanic regressions.

Deposition in south Florida during the Miocene changed with the introduction of more widespread siliciclastics from a fluvio- deltaic system prograding down the peninsula. Phosphates and the carbonate ramp of the Arcadia Formation were deposited during the Miocene in south Florida. A Pliocene lowstand caused many of the previous deposits to be reworked and/or eroded. The Tamiami Formation is a Pliocene marine unit comprising a wide range of rock types. These are predominantly fossiliferous sands and clays with limestone.

The Pleistocene era resulted in the conversion from siliciclastic deposition mixed with carbonate accumulation to more widespread carbonate sedimentation (Cunningham, 2005). Global sea- level changes during the intermittent ice ages of the Pleistocene controlled the rate and distribution of carbonate units. At 120 Ka, the last major sea level fall occurred as the mixed carbonate- siliciclastic sediments formed the Fort Thompson Formation. This unit interfingers with the surficial geologic units, the Miami and Key Largo Limestones, and the Anastasia Formation (~130 Ka) (Cunningham, 2005).

At 15- 16 Ka sea level began to rise rapidly and flood southern Florida around 7 or 6 Ka (Shinn et al., 1997). Sea level has continued to rise. Holocene geologic activity in the Big Cypress area consists of the dissolution of carbonate units, the accumulation of carbonate muds, freshwater marls, sand and swamp (organic peat and muck) deposits.

Stratigraphy

Cores drilled in the oil and gas exploration operations help define the stratigraphy underlying the preserve. In the oil producing area of Big Cypress, the sedimentary section is 4,572 to 5,182 m (15,000 – 17,000 ft) thick. The first 2,134 to 2,743 m (7,000 – 9,000 ft) are Late Jurassic through Early Cretaceous rocks, the next 914 m (3,000 ft) are Late Cretaceous age rocks, and the remaining 1,676 m (5,500 ft) are of Tertiary age to the present (Pollastro et al., 2000). These rocks fill the South Florida Basin, the center of which is located northwest of the Florida Keys. The basin is bounded on the east by the Paleozoic Peninsular Arch (trending northwest – southeast), the Florida escarpment to the west, the Tampa – Sarasota Arch (trending northeast – southwest) to the north, and the Pine Key arch to the south.

Jurassic age basaltic- rhyolitic rocks underlie all of south Florida. Since the Jurassic, sedimentation has kept pace with overall basin subsidence. Deposition has included carbonates, clastics and evaporites (Pollastro et al., 2000). The earliest sediments, of the Wood River Formation are continental clastics overlain by salt, limestone, anhydrite and brown dolomite. Between the Wood River and the oil producing Sunniland Formation lie the predominantly carbonate-evaporite Bone Island and Pumpkin Bay Formations, and the Glades Group of shales, dolomites, and anhydrites (Faulkner and Applegate, 1986). The Sunniland Formation of Lower Cretaceous age is comprised of anhydrites, thin limestone layers, and dolomites. The Sunniland, along with the anhydrite and limestone of the Lake Trafford Formation and the dolomite, limestone and anhydrite of the Rattlesnake Hammock Formation, comprise the Ocean Reef Group.

The Big Cypress Group and Naples Bay Group overlie the Ocean Reef Group. These are largely dolomites and anhydrites beneath Big Cypress. The Upper Cretaceous Pine Key Formation is composed of chalky limestone and dolomite. It is approximately 914 m (3,000 ft) thick. The Paleocene to present day sedimentary layers lie atop the Pine Key Formation at Big Cypress (Faulkner and Applegate, 1986). Relatively uninterrupted Tertiary deposition amassed the grand carbonate platform of South Florida. These sediments reach great thicknesses of approximately 1,676 m (5,500 ft).

Cores drilled in nearby Everglades National Park help determine the upper stratigraphy at Big Cypress. Eocene to late Oligocene deposition consists of marine carbonates of the Avon Park Formation, the Suwannee Limestone and the Ocala Group, and the Arcadia Formation of ramp setting carbonates with scant quartz contents increasing northward (Cunningham, 2005). A major disconformity marks the boundary between the Arcadia Formation and the overlying Peace River Formation. In other areas of Florida, the Hawthorn Group

(Miocene) is between the Arcadia and Peace River Formations. The Peace River Formation contains two distinct units: a lower diatomaceous mudstone, and an upper fine- grained quartz muddy sandstone (Cunningham et al., 1998). Deposited atop the Peace River Formation is the Tertiary age Tamiami Formation. This unit comprises much of the surface outcrop at Big Cypress.

Shallow water limestone of the Fort Thompson Formation underlies the surficial Miami Limestone. This limestone is probably combined with the capping unit of the Miami Limestone. The Fort Thompson is mostly lagoonal facies carbonate with abundant bivalve fossils and some quartz sand. The Miami Limestone is ~125 – 130 Ka and represented deposition during an interglacial period. Two facies exist for the Miami Limestone. The western portion of the unit contains predominantly the bryozoan facies, the unit then becomes more oolitic eastward (Hoffmeister et al., 1974; Cunningham, 2005).

Overlying the Miami Limestone bedrock are surficial units of freshwater peat and organic muck, freshwater marls, and cyanobacteria mats in the swampy marsh at Big Cypress. The peat and muck typically occurs in low- lying sloughs and solution holes and are dark and fine- grained. During the standing water phase of the wet season, extracellular precipitation of calcium carbonate by cyanobacteria forms fresh limestone marls (Cunningham, 2005).

Significant Geologic Resource Management Issues at Big Cypress National Preserve

1. Hydrogeologic system at Big Cypress

The Big Cypress is really a western extension on the Everglades system. Water is flowing on the surface in marshes and sloughs and below ground in slow flowing aquifers through porous substrate. The present topographic and hydrogeologic information is too coarse and/or inadequate for resource management. More modeling is necessary to understand the true water budget of the preserve.

The flow of water through the preserve has been drastically altered and diverted by the construction of roads, trails, pads, canals, and levees. The state and local pumping policies control a vast portion of water input to Big Cypress. Pumping can control basin dynamics. A major goal of the preserve is the restoration of the original flow ways as best as possible. A focus area is the 9 to 12 m (30 – 40 ft) wide Turner River basin in- channel construction near U.S. Highway 41. Restoration efforts include reconnection flows through canals and roads (building causeways). The Bear Island area is another area to focus restoration efforts. Cooperation is necessary between resource management and local water volume management agencies to coordinate and organize the timing responses of gates and pumps.

Regional models achieve varying degrees of success at Big Cypress. The South Florida Water Management Model (SFWMM) ignores roads and uses an outdated climatic scheme. The Natural Systems Model (NSM) uses vegetation patterns to predict an improved pseudotopography. The Across Trophic- Level System Simulation (ATLSS) correlates species with hydrology, hydroperiod, and vegetation. The Everglades Landscape Model (ELM) covers the hydrology of bounded systems of canals and structural control with rain- driven triggers. The Interim Structural and Operational Model (ISOP), which is 2- 3 years from implementation, is probably the closest to the concerted water budget management the preserve needs, but still uses core data from the SFWMM model. Cell size and vertical precision vary on these models from 3.2 km (2 miles) to 30 m (100 ft) and 15 to 3 cm (6 to 1 inches), respectively. LIDAR would improve the vertical precision.

Research and monitoring questions and suggestions include:

- Study how rainfall controls the hydrologic system.
- Does the depth to bedrock measurement have a significant control on the system?
- Compare natural and anthropogenic caused hydraulic changes.

- Monitor hydrologic response to storm events.
- Try to get LIDAR mapping of sloughs for fine- scale topographic changes.
- Obtain more hydrologic sampling and install hydrologic monitoring stations in key locations.
- Determine more stage level measurement points.
- Monitor stage level.
- Attempt to align with the Comprehensive Everglades Restoration Program (CERP) efforts (Big Cypress is largely overlooked in favor of Everglades restoration).
- Cooperate with federal, state, and local agencies to monitor and clean up ground and surface water; examples of pollution include creosote (from Copeland sawmill in the 1960s), agricultural runoff (including pesticides from tomato farms).
- Deep Lake (27 m 90 ft deep) is the southernmost sinkhole in Florida, why?
- Focus geologic studies on processes rather than just features.
- Categorize, describe, and model the near- surface, mid- and deep aquifers below Big Cypress National Preserve.

2. Geologic and topographic mapping

The relief at Big Cypress is approximately 6 cm/km (2 inches/mile) or 4.6 m over 145 km (15 ft over 90 miles). This incredibly low relief is the reason the sloughs, swamps, and marshes thrive at Big Cypress. Water slowly trickles down to the sea from central Florida. High- resolution topographic mapping, when combined with flow patterns would help resource management determine which areas to focus on for restoration.

Research and monitoring questions and suggestions include:
- Relate small- scale topographic differences with the locations of hammacks and pinelands at the preserve.
- Map the locations where the Tamiami Limestone is exposed.
- Focus topography and cross section production on key areas (coordinate with the original flow way restoration efforts).
- Map karst features in addition to canals and rock pits on maps.
- Cooperate with slough mapping project through the Audubon Society.
- Expand upon the Tamiami type section located within the preserve.
- Are strands and paleochannels related?
- Why is the boundary between Big Cypress and the Everglades so dramatic?
- What is the nature of the boundaries between strands?
- Map rock outcrops at different scales and determine if they have a controlling influence on the location of Cypress stands.

- Greg Desmond with the USGS is conducting a High- Accuracy Elevation Project with an Airborne Height Finger (AHF), which creates Digital Elevation Models (DEMs); support him to obtain better data.
- Determine original flow ways with DEMs.
- Suggest more USGS/BLM/NRCS/SFWMD/FLDOT cooperative geologic/mapping projects.

3. Soils and bedrock depth

Soils were identified as an ORV Plan Record of Decision (ROD) information need. A soil survey is needed at the park as well as research on recovery science. Several unique soil units, such as "deep muck" and "cypress strand" exist in the preserve and should be type localities.

Research and monitoring questions and suggestions:
- What is the depth of the soils at Big Cypress?
- Map soil types and depths.
- Study resiliency of soils.
- Research possible options to restore damaged soils.
- Research historical fire data and correlate with soil types.
- Relate near surface limestone (marine or freshwater) and/or peat with soil distributions.

4. Disturbed lands

Disturbed lands besides areas affected by oil and gas operations, include borrow pits excavated for the construction of the oil and gas pads and roads built to access remote sites.

Research and monitoring questions and suggestions:
- Quantitatively identify disturbed sites and explore remediation to restore natural water flow.
- Remove Bear Islands closed oilfield roads.
- Work on finding ways to build bridges and reculvert established road areas to improve flow focusing on roads directly perpendicular to flow first.

5. ORV management

More than 425,145 visitors came to the preserve in 2004. These visitors enjoyed the incredible recreational opportunities at Big Cypress. Activities include camping, kayaking, hiking, bird watching, canoeing, hunting, ORV use, and airboat access. The preserve is attempting to concentrate visitor access to reduce environmental impact.

Raised roadbeds across south Florida have dammed the natural, low relief, slow moving sheet- flow from Lake Okeechobee to Florida Bay. ORV use at Big Cypress has caused major damage to the hydrology and soils. Soil resiliency at the preserve is not well understood. Buggies and other ORVs destroy algae (terraphytes) populations in the soils. The entire ecosystem is based on these microorganisms that lie dormant in dry conditions. When they are churned up and buried, the landscape resembles a soil desert. An ORV management plan, completed in 2001, calls for a designation of 644 km (400 miles) of trails in the preserve. It is estimated that at least 22,000 miles of trails currently exist. For a park the size of the state of Rhode Island, the ranger on duty has difficulty patrolling the ORV activity. Unauthorized airboat use is also a resource management issue affecting water quality, noise levels, and soils.

Research and monitoring questions and suggestions include:

- Determine the best sites for a designated trails system.
- Perform a preserve- wide soils survey to establish baseline conditions for trail planning.

6. Oil and gas issues

Oil and gas exploration began in the Big Cypress area in 1923. Most of the active drilling was in the mid 1970's. The main producing geologic unit is the Sunniland Formation. Approximately 450 wells have been drilled along the northwest – southeast oriented Sunniland Trend. Oil and gas activity in the preserve is rapidly declining. As of September 2004, there are 18 wells producing from only eight fields. Eight of these producing wells are located within the preserve. The oil and gas reservoir rocks are porous (10- 30% porosity). They are composed of carbonate grainstones and dolomites sealed by evaporites and/or nonporous carbonates. Based on 2D seismic surveys, gravity and magnetics data, the overall drilling success rate has been about 3% (Norby, 2005).

Most of the oil and gas rights under the preserve are of private ownership, established prior to the designation of the preserve. Ninety- nine percent of the land at the preserve is "split estate" meaning the surface and subsurface ownership is different. The pads and roads left behind when a well is closed leave a large scar on the landscape and affect the hydrologic system at Big Cypress. Roads are built of borrow pit material 1.2 m (4 ft) higher than the surrounding drainage. Culverts are thinly spaced and many are falling into rusty disrepair. The responsibility for monitoring, compliance with regulations, restoration and remediation is often unclear and pipes, wells, and structures are still at abandoned pads.

Research and monitoring questions and suggestions:

- Explore making a depth to bedrock measurement mandatory per shot hole for oil and gas exploration.
- Obtain seismic information per township on a grid pattern.
- Use road and pad fill for trail construction and other remediation work.
- Work with corers to obtain more stratigraphic data.
- Attempt to update the Minerals Management Plan to have stronger surficial protection regulations.

Scoping Meeting Participants

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Map of Big Cypress National Preserve